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TIME DELAY RELAYS FOR AIRCRAFT APPLICATIONS

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ABSTRACT

An investigation was conducted to determine methods of obtaining time delay in aircraft relays in which the delay is not to be adversely affected by current, voltage, atmospheric pressure, vibrations, or ambient temperature changes. Various means of obtaining time delays were investigated, both theoretically and experimentally. Two types of relays found to have good possibilities were a thermal and an electromechanical type. The thermal type containing two electrically heated bimetal strips gives a fair degree of accuracy but requires at least 45 seconds recycling time. The electromechanical type contains a timing motor whose speed is controlled by a vibrating reed. It has good accuracy and can be recycled almost instantly. Further development of both types is recommended. A constant current device should be incorporated into the thermal type so as to make it reasonably independent of applied voltage. Size, weight and susceptibility to vibration should be improved upon in the electromechanical type.

PROBLEM STATUS

This report concluded the work on this problem and, unless otherwise advised by the Bureau, it will be closed one month from the mailing date of this report.

AUTHORIZATION

NRL Problem No. E05-01 (BuAer Problem No. 31E116).

TIME DELAY RELAYS
FOR AIRCRAFT APPLICATIONS

INTRODUCTION

There are numerous applications for aircraft time delay relays in which the delay should not be adversely affected by current, voltage, ambient temperature, or pressure changes. In some instances the relay should be capable of immediate recycling. The following limiting values of voltage, temperature, and pressure were established with the above requirements in view:

The relay should be nominally rated at 28 volts d-c, and should not be adversely affected by voltage changes from 20 to 30 volts; it should operate satisfactorily in ambient temperatures ranging from -55°C to +70°C, and in pressures from 3.5 inches to 30 inches of mercury. Delay periods should be adjustable from 5 to 10 seconds, 10 to 20 seconds, or 20 to 30 seconds.

There are several types of time delay relays available for use on 115 volts a-c and a few for 28 volts d-c. A large percentage of these have been designed for industrial usage, however, and few, if any, are applicable to aircraft. The majority of the a-c types, for example, use a synchronous motor to produce the delay periods, hence a supply source with an accurately controlled frequency is necessary. A pneumatic relay containing a mercury switch employs a unique principle. In this unit the time delay is obtained by the restricted flow of an inert gas through a ceramic material, the gas and ceramic being hermetically sealed in a tube. This device is independent of voltage and pressure, but is affected by temperatures since mercury freezes at approximately -39°C. The time delay is not adjustable and the unit must be kept in an upright position. Oil dashpots are frequently used to obtain delay periods but the viscosity of oil is subject to change with temperature variations. Bimetallic materials are used extensively in timing devices in which the delay period is obtained by heating bimetal strips. The thermal types developed thus far are generally susceptible to changes in supply voltage and ambient temperature, and few of them have adjustable delay periods. There are many methods of securing a time delay by the use of vacuum-tube circuits such as multivibrators and the several types of oscillators, but the necessary power supplies and circuit components would be prohibitive in size and weight for aircraft use. Resistive, capacitive, and inductive elements can be used in various combinations to produce delay, principally of short duration; if longer periods are desired, the components become bulky. This method, and the one using vacuum tubes, would be considerably affected by changes in applied voltage, therefore a constant potential supply would be necessary.

Few of the above types of relays and principles meet the requirements for satisfactory operation under conditions of temperature, pressure, and voltage variations which are encountered in present day aircraft applications. Those that are worthy of further consideration, however, are the (1) pneumatic, (2) thermal, and (3) electromechanical types.

PNEUMATIC TYPE RELAY

One method for obtaining a time delay employs a metal bellows, a solenoid, and a compression spring as shown in Figure 1. Since the metal

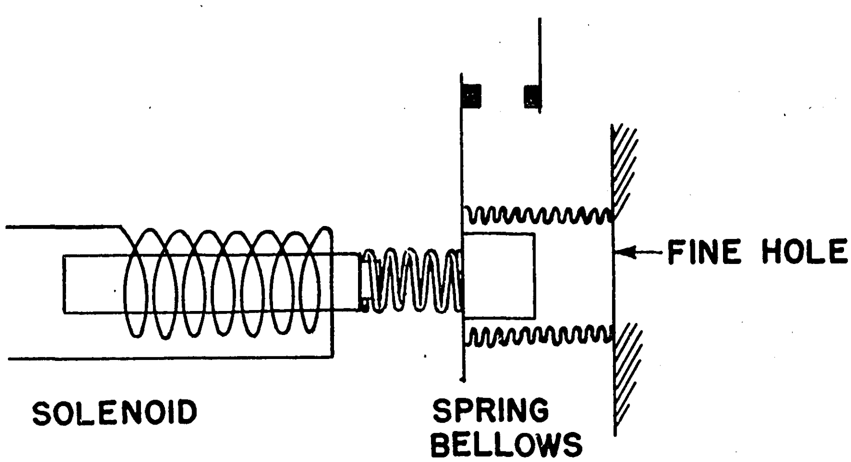

Figure 1 - Pneumatic Relay

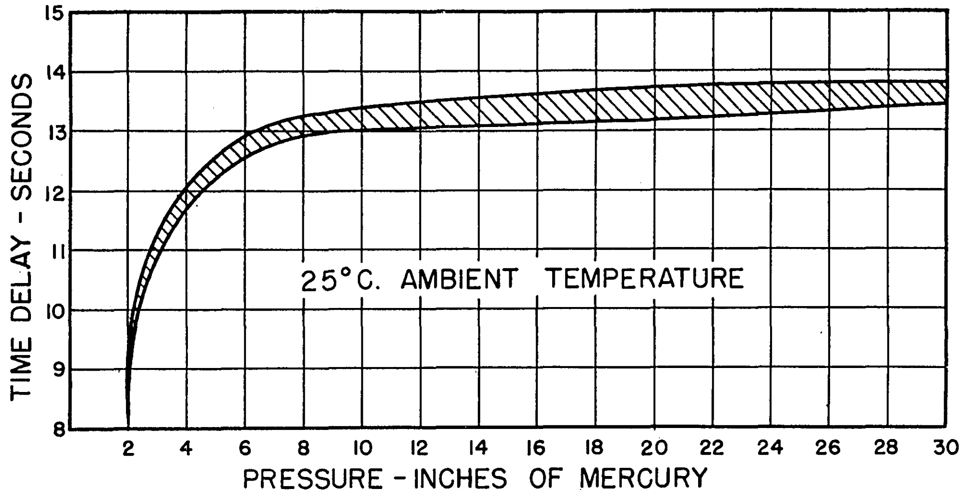

Figure 2 - Pressure Effects on Time Delay of Commercial Pneumatic Relay

bellows are intended for compression up to about 50 percent of their active length, it was necessary to reduce the interior volume to nearly zero at 50 percent compression by inserting a closed metal container. A solenoid compresses a spring which in turn compresses the bellows, forcing the air out of a very small hole, 0.0135 inch in diameter. As the air escapes, the spring end of the bellows moves to the right, closing a contact after a time delay. The maximum delay obtained, however, is approximately one second.

A commercially available pneumatic type relay based on the same principle as the bellows, but utilizing a diaphram, was obtained. This unit differs from the above relay in that when the solenoid is energized, it compresses a spring instantly which forces air out of an enclosure through an adjustable needle valve. The time delay range of this device is from a fraction of a second to approximately 60 seconds. It should be noted that the delay period will not be affected by variation in applied voltage if the minimum voltage (20 volts) will produce full solenoid travel. The effect of pressure on the time delay for this relay is presented in Figure 2. The accuracy of the timing is indicated by the vertical width of the band. The rapid drop in the delay time at low pressures could be eliminated by hermetically sealing the relay but it would then be very difficult to adjust the time delay period. The effect of temperature on the time delay is shown in Figure 3. At -56.7 °C the plunger stuck and failed to close the contacts.

The advantages of the pneumatic relay, therefore, are that it is (1) independent of applied voltage, (2) unaffected by pressure changes (when sealed), (3) immediately available for recycling, and (4) simple in design. Its disadvantages are (1) difficulty of delay adjustment (when sealed), (2) inaccuracy of timing, particularly with temperature changes, and (3) maintenance difficulties arising from the troublesome metering orifice.

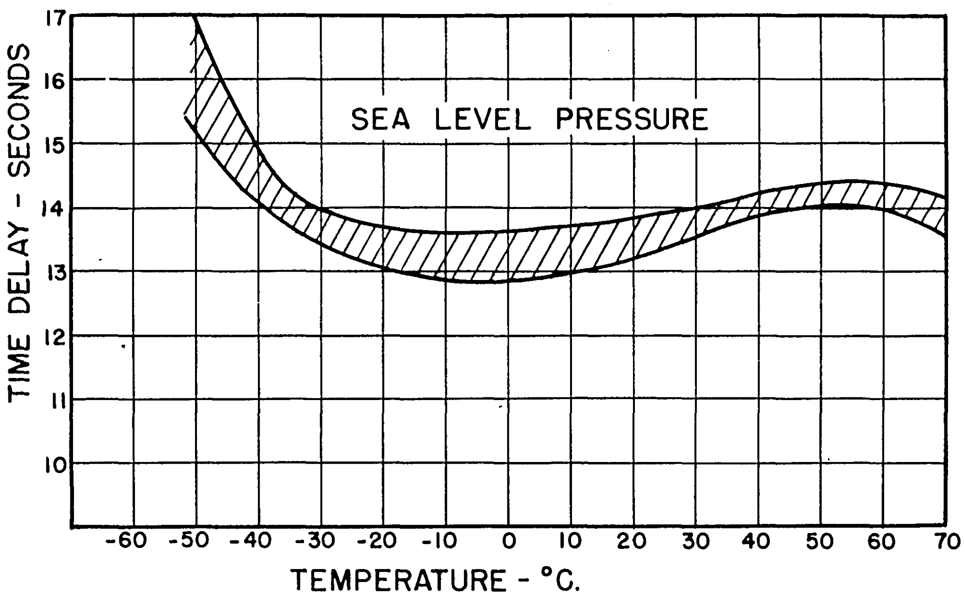

Figure 3 - Ambient Temperature Effects on Time Delay of Commercial Pneumatic Relay

THERMAL TYPE RELAYS

The pneumatic type relay offers some difficulty at low temperatures and pressures, therefore two types of delay relays employing a thermal principle were considered. One of these types utilized negative temperature coefficient resistors as the element for determining the delay period. Circuits employing this principle are shown in Figures 4 and 5. Certain problems not immediately apparent render it very difficult to make these circuits usable for producing time delays. In the case of either circuit it is necessary to provide a constant potential supply and accurately calibrated solenoids. Temperature compensation then becomes a problem. For

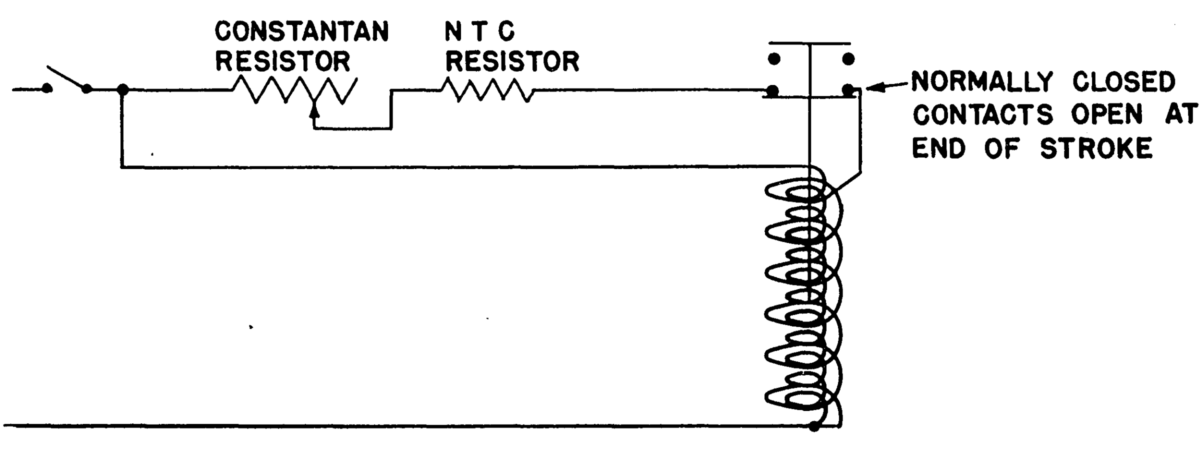

Figure 4 - Thermal Relay Using Negative Temperature Coefficient (NTC) Resistors in a Series Circuit

the circuit of Figure 4 there is no known resistor material with a sufficiently large positive temperature coefficient to counteract the effect of the large negative coefficient available. Using identical materials for R_1 and R_2 (negative temperature coefficient) in Figure 5 partially compensated for changes in ambient temperature, but not sufficiently for satisfactory operation.

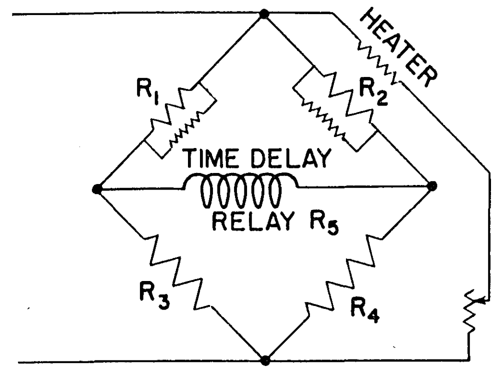

Figure 5 - Thermal Relay Using Negative Temperature Coefficient Resistors in a Bridge Circuit

A thermal relay employing negative temperature coefficient resistors has the advantage of being (1) inexpensive to produce, and (2) unaffected by pressure changes. The disadvantages, however, are (1) the necessity of providing a constant potential supply, (2) the inability to compensate adequately for ambient temperature changes, (3) the necessity of using accurately calibrated solenoids, and (4) the device is not immediately available for recycling.

A second type of time delay relay which depends upon the action of bimetal strips was considered. Although such a device could take many forms, that which appears to offer the greatest advantage is shown in Figure 6. The operation of this unit is as follows:

When the switch is closed the circuit is completed through a normally closed contact of the relay to the heater on the left bimetal strip. The strip bends to the right, closing the contact which energizes the relay. The relay remains energized by a holding contact. The heater on the left strip is now disconnected, which allows the strip to cool. At the instant the relay is energized the heater circuit on the right strip is closed through the spring contact on the strip. This causes the right strip to bend to the right, which opens the circuit to its heater after a few seconds. The right strip is thus brought to approximately the same temperature as the left one. After the strips cool somewhat, the delay relay is ready for another cycle when the relay is de-energized. The variable resistance R controls the time delay period.

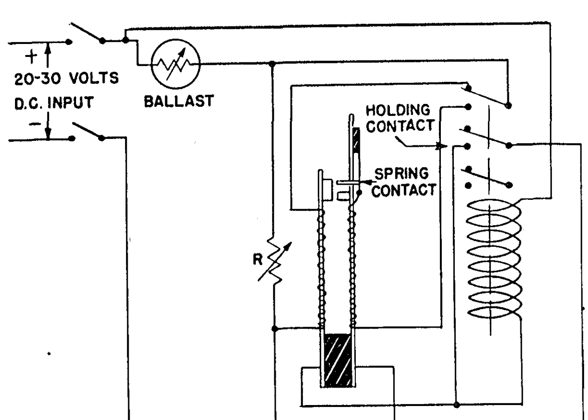

Figure 6 - Thermal Relay Using Bimetal Strips

The time delay period is independent of atmospheric pressure. Figure 7 shows the variation in time delay with changes of ambient temperature. Accuracy is indicated by the vertical width of the band. This curve was obtained with a constant emf of 12 volts impressed across the thermal element.

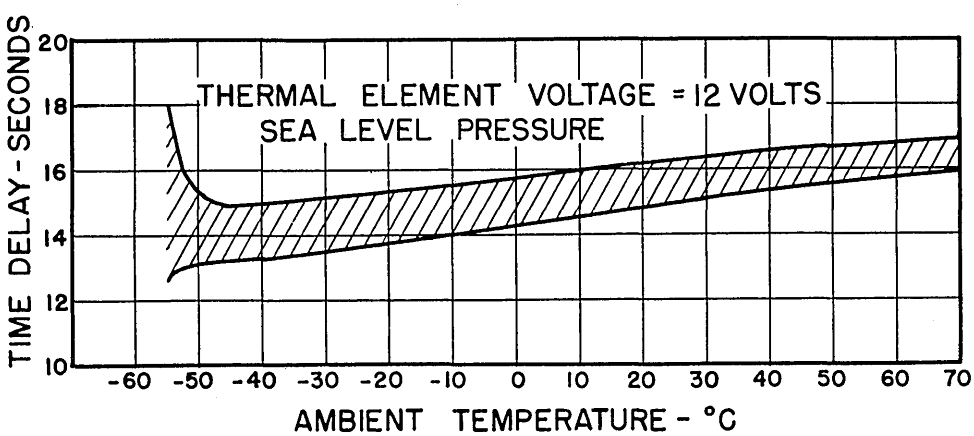

Figure 7 - Ambient Temperature Effects on Time Delay of Thermal Relay

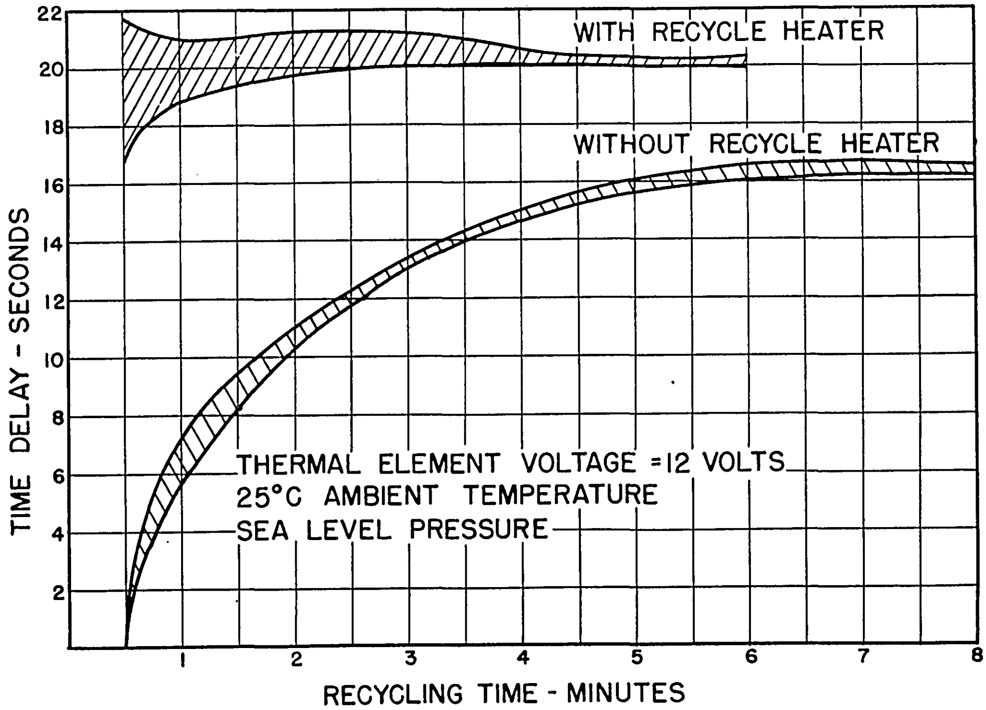

Figure 8 - Effect of Recycling Time on Time Delay of Thermal Relay

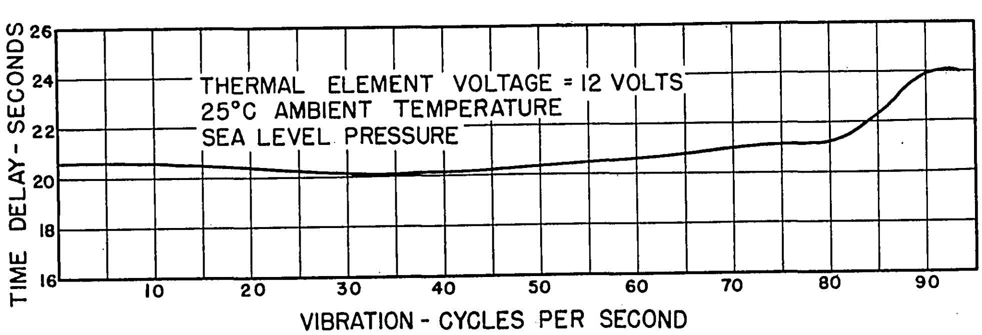

Figure 9 - Vibration Effects on Time Delay of Thermal Relay

This type of relay would be one of the least expensive to produce. The disadvantage in the application of this unit may be found in the length of the recycle period. Because of the inherent thermal inertia, a period of time is required to cool the heated bimetal strip between operations. However, through the application of the "recycle heater" on the right bimetal strip, it was possible to reduce the recycle time from approximately six minutes to 45 seconds as shown in Figure 8.

Vibration applied parallel to the motion of the contacts was found to have little effect on the time delay period except at 90 cps (Figure 9). This test was conducted using an amplitude of 0.05 inch. It should be noted that the characteristic presented in Figure 9 is for one particular design. By changing the size and shape of the bimetal strips the resonant frequency can be changed.

The thermal type employing bimetal strips has the advantage of being (1) simple and inexpensive, (2) reasonably free from the effects of vibration, (3) unaffected by pressure, and (4) free of complicated mechanisms which could get out of order. Its disadvantages are (1) the necessity of providing a constant current supply, (2) the recycling period is approximately 45 seconds, and (3) it is slightly affected by changes in ambient temperature.

ELECTROMECHANICAL TYPE RELAY

The inherently long recycle period for the thermal type relay necessitated consideration of some other principle that was free of this characteristic. An electromechanical system was found to have accuracy superior to that of the thermal type in addition to giving an instantaneous recycle time. One method of constructing such a device would be to utilize a rotary type solenoid to impart force through a spring to a set of gears, the rotation of the gears being restrained to give constant speed by means of an escapement wheel, and the speed of the latter being controlled by the vibrating motion of a small mass. The rotation of the gears would close electrical contacts, thus completing the closing cycle. Return of the contacts and solenoid to the initial position would be accomplished by the force of a second spring. Such a device would be free of all effects of temperature, pressure, and voltage and would provide almost instantaneous recycle time. This type relay could be designed to provide the time delay period when energized or de-energized.

Another type of electromechanical relay utilizing a constant speed d-c motor was constructed. The speed of the motor is controlled by a vibrating reed which contains an electrical contact through which the motor current must pass. This motor, commercially available and having speed characteristics as shown in Figures 10 and 11, was used in conjunction with a special magnetic clutch and switch arrangement. The complete device is shown in Figure 12 and the wiring diagram is presented in Figure 13. Operation of this unit is as follows:

When power is applied to the relay, the magnetic clutch is energized and the motor, which is connected through a normally closed contact of the

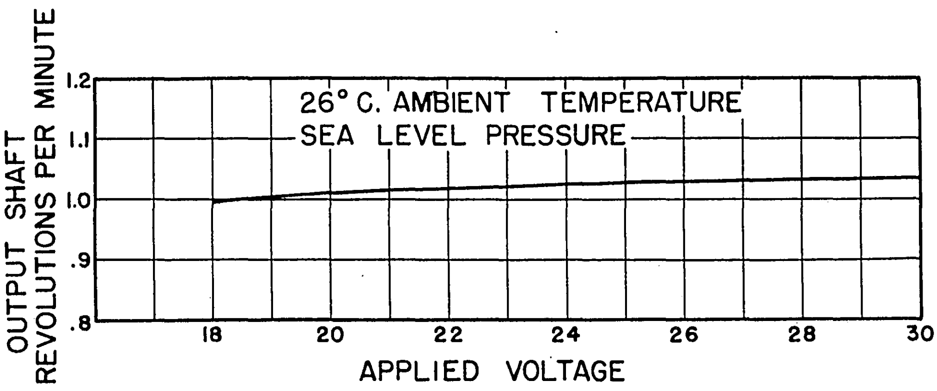

Figure 10 - Constant Speed D-C Motor

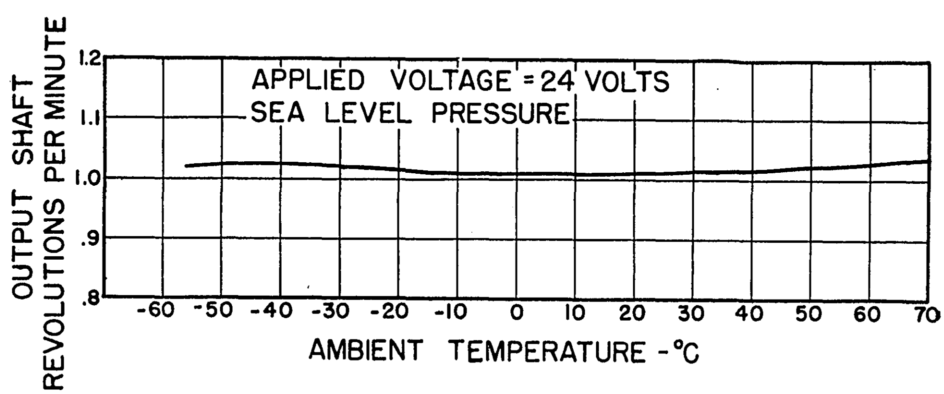

Figure 11 - Ambient Temperature Effects on Constant Speed D-C Motor

switch, starts driving the cam through the clutch. After the prescribed time interval, the cam operates the switch and the motor stops. The clutch remains energized, holding the cam and switch in the energized position. When the relay is de-energized, the clutch slips, allowing a spring to return the cam to the original position determined by a set screw, the adjustment of which determines the time delay period. The contacts are returned to their unenergized position. The relay is then ready for another cycle. If the relay is energized and then de-energized before the end of the time delay period, the clutch slips, allowing the cam to return to its original position. The recycling time is therefore a fraction of a second even when the device is interrupted during the time delay period.

The effect of voltage changes on the delay period for four settings of the timing adjustment (at approximately 5, 10, 20, and 30 seconds) is presented in Figure 14. The maximum variation was 3.9 percent at 30 seconds. The effect of ambient temperature changes on the time delay at voltages of 20, 24, and 30 volts is shown in Figure 15. The maximum variation in time delay at these voltages was 5.2, 3.4, and 2.9 percent respectively. It should be noted that as the voltage increases, the effect of ambient temperature on the time delay decreases.

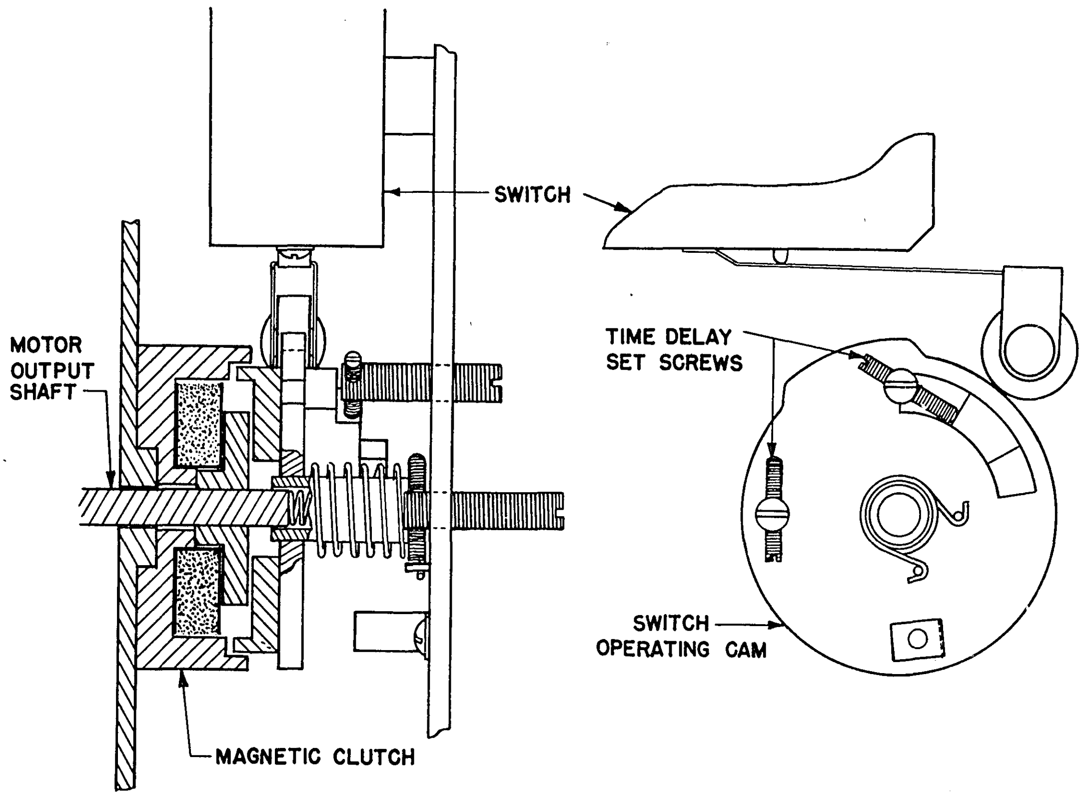

Figure 12 - Magnetic Clutch and Switching Arrangement for Electromechanical Relay

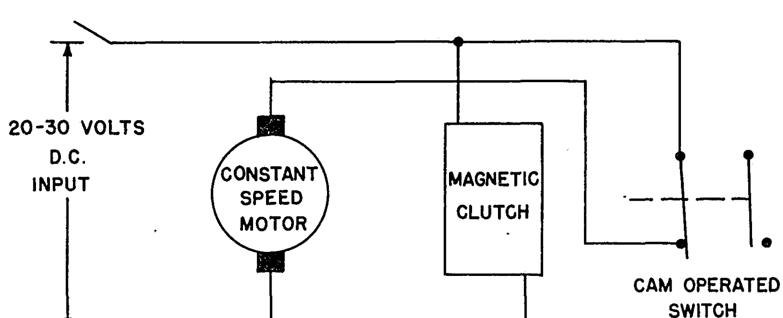

Figure 13 - Wiring Diagram of Electromechanical Relay

The relay was subjected to a vibration of 0.06 inch total excursion and frequencies from 10 to 55 cycles per second, parallel to the axis in which the motor reed vibrates. The relay operated satisfactorily up to approximately 30 cycles per second. Above 37 cycles the motor would not start. As the amplitude of vibration is reduced, the frequency at which the motor refuses to start is increased. When the relay was subjected to vibrations in the other two mutually perpendicular directions it was affected to a lesser degree but enough to be objectionable.

The advantages of the electromechanical type relay may be summarized as (1) being practically independent of pressure, temperature, and applied

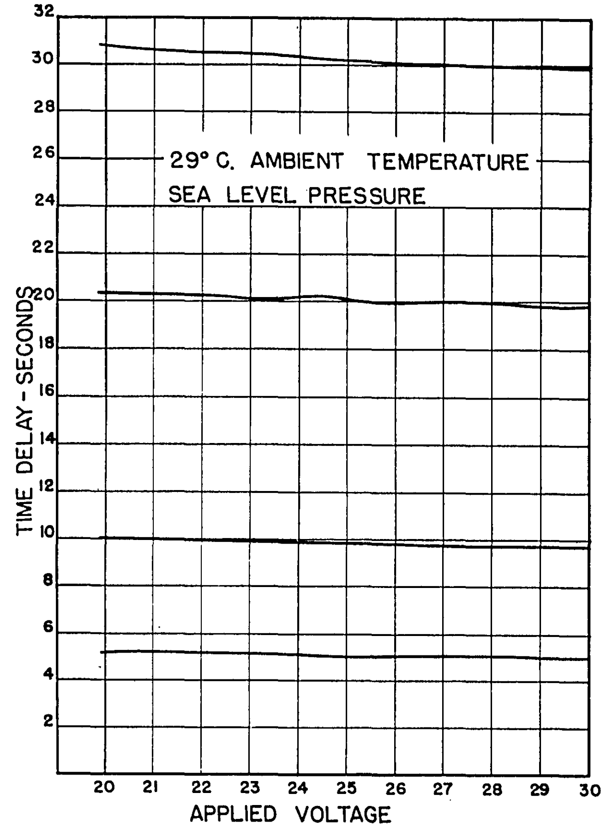

Figure 14 - Time Delay of Electromechanical Relay as a Function of Applied Voltage

voltage, (2) having an extremely short recycling time, and (3) having very accurate delay periods. Its disadvantages are (1) its large size and weight, (2) its complicated and expensive mechanism, and (3) its susceptibility to the effects of vibration.

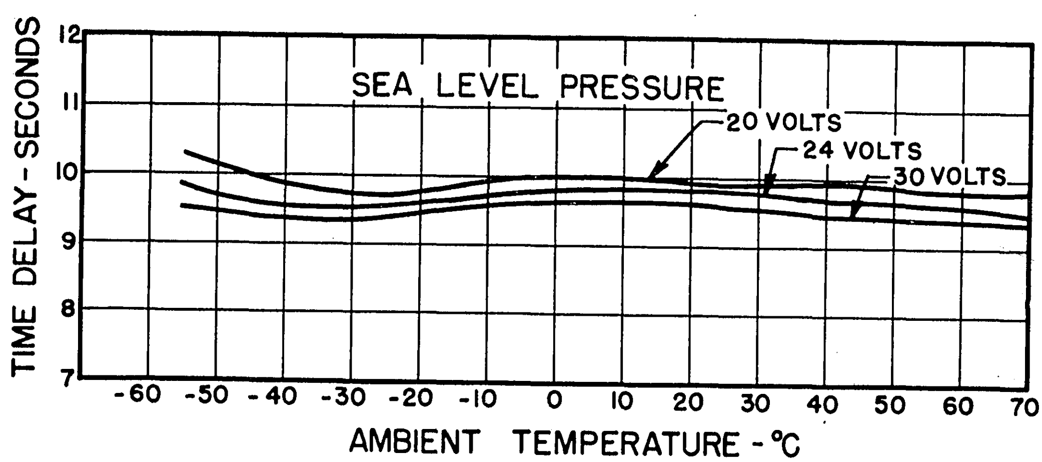

Figure 15 - Ambient Temperature Effects on Time Delay of Electromechanical Relay

CONCLUSIONS

The analysis of the methods for obtaining time delay periods in relay operation on naval aircraft reveal the following characteristics:

Pneumatic Type Relay

Advantages:

(1) It is independent of applied voltage.
(2) It is unaffected by pressure changes (when hermetically sealed).
(3) It can be recycled immediately.
(4) The design is simple.

Disadvantages:

(1) The delay adjustment is difficult to accomplish (when hermetically sealed).
(2) The timing periods are not accurate, particularly with ambient temperature changes.
(3) Maintenance difficulties arising from the troublesome metering orifice.

Thermal Type Relay Employing Negative Temperature Coefficient Resistors

Advantages:

(1) It is inexpensive to produce.
(2) It is unaffected by pressure changes.

Disadvantages:

(1) A constant potential supply must be provided.
(2) Completely adequate compensation for ambient temperature changes cannot be made.
(3) Accurately calibrated solenoids must be used.
(4) It cannot be recycled immediately.

Thermal Type Relay Employing Bimetal Strips

Advantages:

(1) It is simple and inexpensive to produce.
(2) It is reasonably free from the effects of vibration.
(3) It is unaffected by pressure changes.
(4) Free of complicated mechanisms which could get out of order.

Disadvantages:

(1) A constant current supply must be provided.
(2) The recycling time is approximately 45 seconds.
(3) It is slightly affected by changes in ambient temperature.

Electromechanical Type Relay

Advantages:

(1) It is practically independent of changes in pressure, ambient temperature, and applied voltage.
(2) The recycling time is extremely short.
(3) The delay periods are very accurate.

Disadvantages:

(1) The size and weight are excessive.
(2) The mechanism is complicated and would be expensive to produce.
(3) It is susceptible to vibration.

RECOMMENDATIONS

It is recommended that the electro-thermal relay containing bimetal strips be used in preference to the more expensive and more complicated electromechanical type, where great accuracy is not required and the recycling time is not an important factor. The application of the device will dictate the necessity of providing a constant current source in order to make the relay independent of applied voltage.

It is also recommended that the electromechanical type relay consisting of a constant speed d-c motor, clutch, and switching mechanism, be developed to produce a small, compact, light-weight time delay relay which will be free of the effects of vibration.

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